VA TECH

VA TECH HYDRO

KAPLAN / PROPELLER TURBINES & GENERATORS

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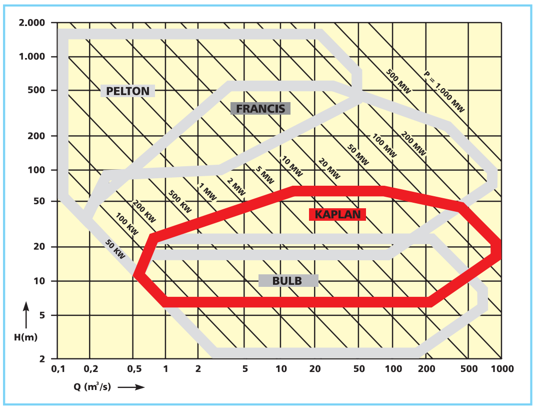
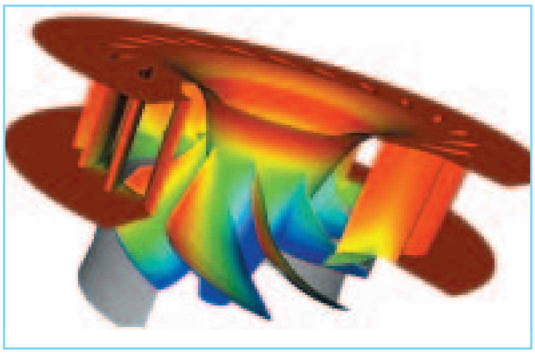
General

Kaplan- and Propeller turbines are most suitable for low head applications in the range of 20 m to 70 m. The unit output today reaches the 200 MW range for the largest applications. Runner diameters of 10 m and more are also standard today.

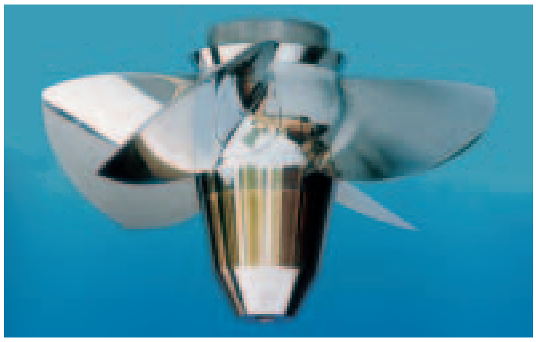




The experience of VA TECH HYDRO regarding Kaplan turbines is approx. 700 units and the output installed is more than 18,000 MW worldwide. Depending on the head range there are Kaplan runners with 3 to 8 blades used today. Beside the very low head applications of Bulb- and Pit turbines which have a horizontal setting the general arrangement of Kaplan- and Propeller turbines is a vertical shaft design.

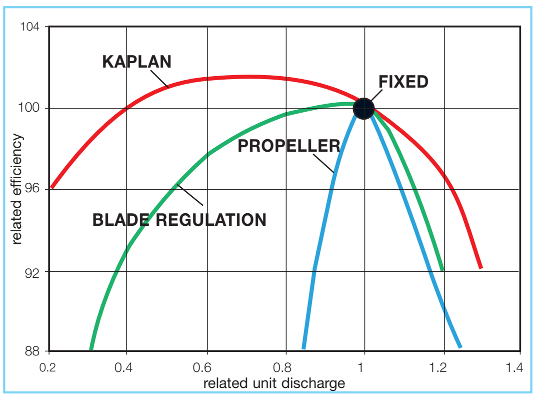
Up to approximately 30 m of head a concrete spiral casing is possible whereas for higher heads full steel plate spiral cases have to be used.

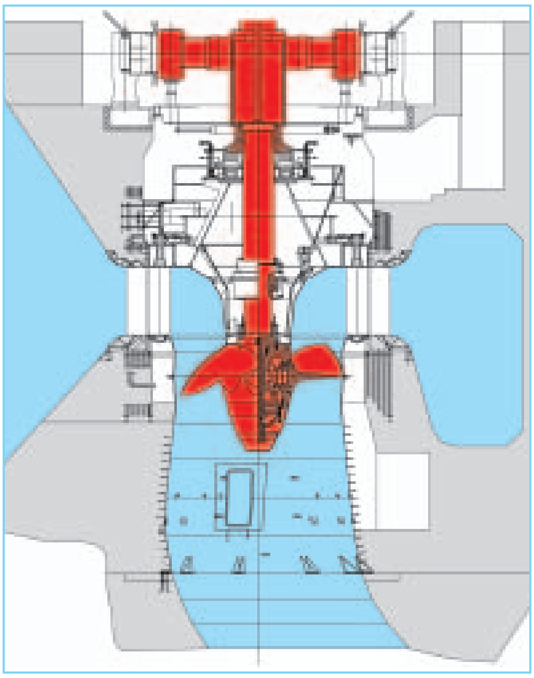
All types of regulation are possible today: since the Austrian Victor Kaplan has invented this type of turbine in the beginning of the 20th century, a full Kaplan turbine has ad-

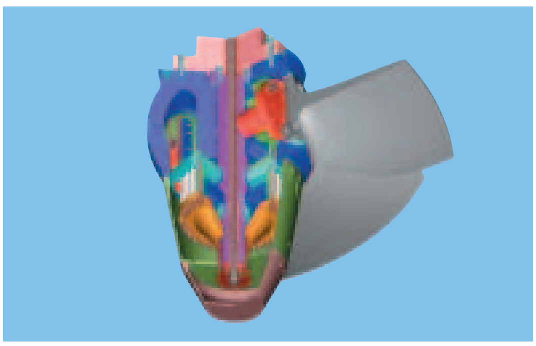


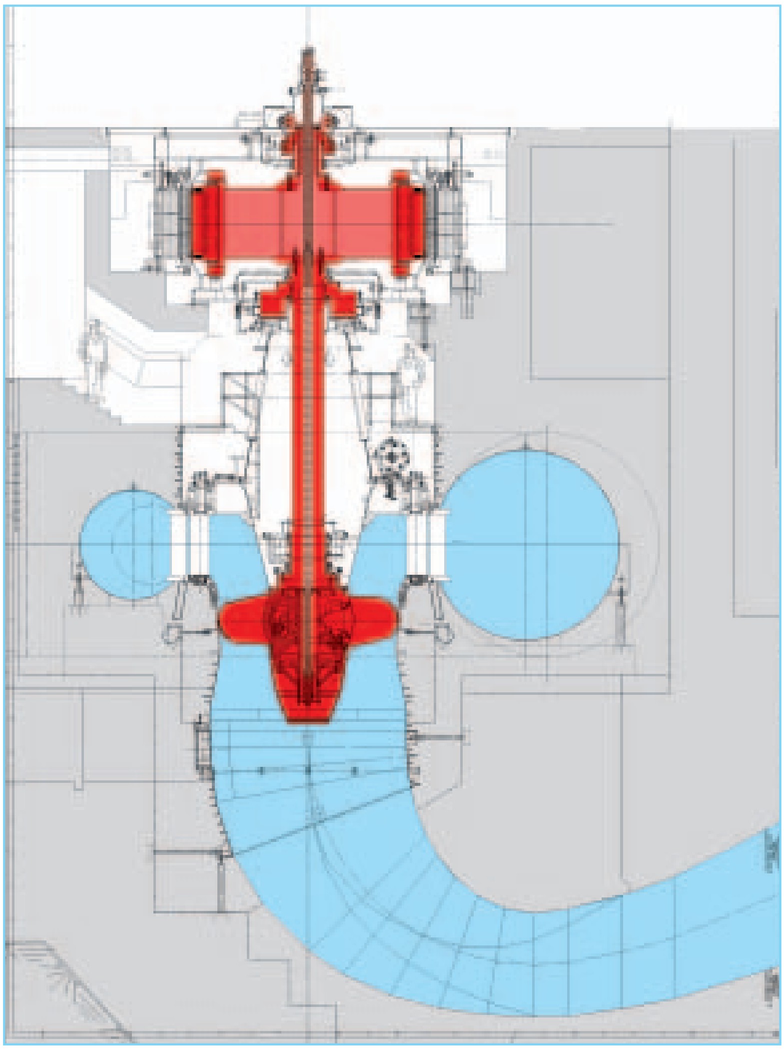
justable blades and adjustable wicket gates to better perform according to the changing water discharge. A Propeller turbine has fixed runner blades and only adjustable wicket gates for regulation and stopping the machine. This is comparable to a classical Francis turbine concept.

A much wider range of regulation can be achieved by using adjustable blades and fixed wicket gates - thus the stopping of the machine has to be done by a gate. When head and discharge are nearly constant over









the entire operating range, a concept with fixed wicket gates and fixed runner blades is the most feasible solution.
Today the development of Kaplan turbines is done by numerical analysis (CFD) as well as finetuning by model testing.
Within VA TECH HYDRO this will be done in the Hydraulic Laboratory in Linz, Austria.
All components of large Kaplan turbines are designed using Unigraphics CAD-system according to the latest design developments. Stress analysis of each component is done by FE-methods.

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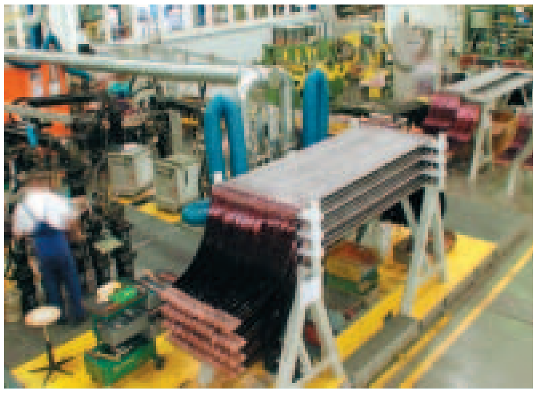
Generator

VA TECH HYDRO generators are a synonym for state of the art design, high efficiency and long lifetime. VA TECH HYDRO has more than 110 years of experience in design and manufacturing of all kinds of generators, from slow speed to highest one, with air- or direct water cooling, from several kVA to more than 300 MVA. More than 33,000 MVA installed worldwide show the impressive capability of VA TECH HYDRO with many references for vertical and horizontal hydro generators including bulb type units and reversible speed motor-generators, for turbo generators and for special applications, like single phase machines.

For engineering of hydro generators the most advanced computer based design technologies like 3-D CAD, CFD for optimisation of cooling air circuits or FEM for mechanical calculations are used together with own developed programs, representing the engineering experience accumulated in more than 110 years. Permanent improvement of the product is based on own developments in cooperation with universities. The possibility of manufacturing a complete generator in one workshop allows shortest deliveries and grants high quality standards. Additionally VA TECH HYDRO has much experience in cooperation with local partners and subcontractors. A sophisticated quality assurance is used to guarantee high reliability and long life of the products. Modern tools are used including 6-sigma methods for permanent quality improvement.



Generators driven by Kaplan turbines have typically slow speeds resulting in large diameters. Stator bore diameters of more than 10 meters are not unusual. Special precautions are necessary to guarantee stator roundness in cold and hot stage. Although the rated speed is slow, the runaway speed of these units is 3 times higher and the rotors must safely withstand this possible failure operation. Typically laminated yoke rims are used which usually are based on friction to obtain a permanent shape for reliable balance. For low vibrations, rims do not float below load rejection speed. Long lasting experience with tangential guidance provides low eccentricities at runaway speed.
Depending on the speed the generator has one or two guide bearings. The thrust

bearing, usually combined with a guide bearing, is of segmental type with pivot supports. The bearings are usually of self lubricating type and motor driven pumps are only used for high pressure oil relieve during start up and shut down of the units. The core components of each generator are stator core, stator winding and field poles. The stator winding is insulated by a VPI (vacuum pressure impregnation) system of outstanding quality. It has an inner potential grading and an outside corona protection including end potential grading. A modern elastic winding fitting (EWB) system is used to fix the winding firmly, safely and durably in the stator core. If requested, other proven methods can also be applied. The stator core is built up of low loss electrical steel sheets, insulated on both sides. Pressing bolts of high tensile steel allow high elongation values and permanent pressing of the core. Pole winding coils are made of straight copper strips connected at the corners by brazing. The coils are built up accurately by use of a CNC automated device. All insulation materials are flame resistant and self extinguishing; therefore a fire fighting system is not necessary.

Highlights

1924 First Kaplan turbine supplied to Waldenburg in Germany with a runner diameter of 2,100 mm and an output of 750 kW

1928 First large Kaplan turbine with a runner diameter of 7 m and an output of 30,000 kW for Schwoerstadt, Germany

1947 Four Kaplan turbines supplied for Blondel (Mondragon) with an unit output of 51.5 MW

1950 First Kaplan turbines with a runner diameter of 7,200 mm supplied for Birsfelden in Switzerland

1951 First highhead Kaplan turbine for Barcis, Italy with a head of 63.5 m

1953 Fourteen Kaplan turbines supplied for The Dalles Dam in USA with 92.2 MW output and 7,112 mm runner diameter

1954 Five Kaplan turbines and generators supplied for Ybbs-Persenbeug in Austria with an runner diameter of 7,400 mm and an output of 34.4 MW each. First stator bore diameter of 10 m

1960 Kaplan turbines with a runner diameter 8,400 mm and an output of 73 MW and generators with a stator diameter of 13,000 mm for Aschach, Austria

1961 Twenty five Kaplan turbines supplied for John Day, Lower Monumental and Little Goose on the Columbia River in the USA with a runner diameter of 7,925 mm and an output of 158.3 MW each

1974 Two Propeller turbines for Kainji, Nigeria with 128.7 MW and 6,800 mm runner diameter

1998 Refurbishment of six large Kaplan turbines of the Iron Gate with a runner diameter of 9,500 mm and an output of 200 MW each

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Aswan Egypt

The Nile which is one of the longest rivers in the world with an approximate total length of 6,825 km has the oldest and most extensive hydrological records.

For more than 7000 years the Egyptians have tried to restrain the regular floods of the Nile and therefore several dams were erected along the river. One of these dams is the Aswan Dam which was erected between 1898 – 1902. In 1948 Escher Wyss Zürich was awarded – by the Upper Egypt Power Authority – with the contract to supply the turbines for the new hydropower station which was erected next to the existing dam. The tailwater of the power station is connected to the river behind the dam via two large tunnels.
The power station is equipped with 7 vertical 5 blade Kaplan turbines for the main power production. Additionally two small auxiliary powerhouse turbines are installed to enable a blackstart when the grid is down and no power from outside can be supplied.

Later on the Nasser Dam upstream of the Aswan Dam was constructed so that the tailwater reservoir of the Nasser Dam is the headwater reservoir of the Aswan Dam. Due to that reason the design head of 32 m will no longer be reached anymore and the Aswan turbines will now be operated at a head of approx. 22 m and a power output of 38.6 MW.

Technical data:		
Output:	47.8	MW
Head:	32	m
Speed:	100	rpm
Runner diameter:	5,600	mm

Hydro

Aschach
Austria

The Aschach Power Station was built as second Austrian power station on the river Danube in the years 1959 to 1964 and is located in Aschach approx. 20 km northwest from Linz in Upper Austria.

With the building of this station, a 40 km stretch of the Danube between Jochenstein and Aschach has been opened for power generation and navigation has been improved in this very narrow part of the river valley. Power generation efficiency is enhanced by the large head and the high winter percentage of annual energy. The powerhouse is of the semi-outdoor type, equipped with a 220 t capacity gantry crane travelling on the crest across the whole structure. Situated between the locks and weir, it is connected to the switchyard and operational building by bridges above the tailwater. Four vertical shaft Kaplan turbines with a rated output of 73 MW each are coupled to generators of 85 MVA.

The turbine runners are 8.4 m in diameter and have been the largest in Western Europe at the time of delivery in 1963 and are situated 3.50 m below mean tailwater level. Also the outerdiameter of the generator-stator with 13 m is the largest diameter of a VA TECH HYDRO generator. Beside turbines and generators, the scope of supply includes also the main transformers, everything designed, manufactured and commissioned by VA TECH HYDRO.

Technical data:		
Output:	**73 MW / 85**	**MVA**
Voltage:	**10.5**	**kV**
Head:	**17**	**m**
Speed:	**68.2**	**rpm**
Runner diameter:	**8,400**	**mm**
Stator diameter:	**13,000**	**mm**

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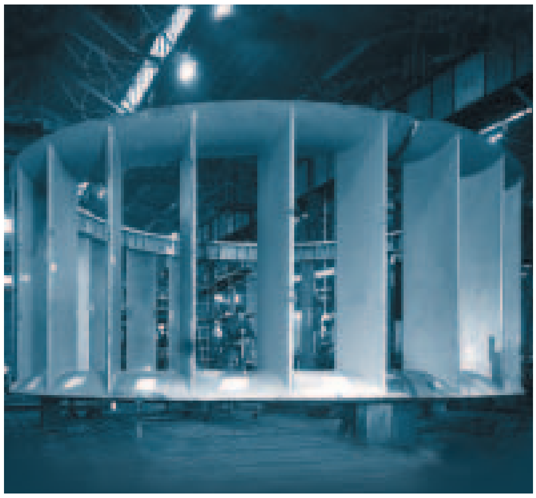
John Day, Lower Monumental, Little Goose/ USA

The John Day Dam is located at the head of Lake Celilo, about 330 km upstream from the mouth of the Columbia river. The dam crosses the river near Rufus, Oregon about 40 km upstream from The Dalles, just below the mouth of the John Day river.

The project consists of a navigation lock, spillway, powerhouse and fish-passage facilities on both shores. Construction began in 1958, the first of the 16 main units began operation in 1968, the last in 1971. Completion of John Day Dam marked the final step in harnessing the waters of the Lower Columbia River. At peak production the powerhouse is capable of producing 2,500 MW, enough to meet the electrical needs of two cities the size of Seattle.



VA TECH HYDRO has supplied all together for the three power plants John Day, Lower Monumental and Little Goose 25 units of Kaplan turbines of the same size and output. The turbines were manufactured by Baldwin-Lima-Hamilton from Philadelphia at that time.

Technical data:		
Output:	**158.3**	**MW**
Head:	**28.7**	**m**
Speed:	**90**	**rpm**
Runner diameter:	**7,925**	**mm**

Hydro

Jupia
Brazil

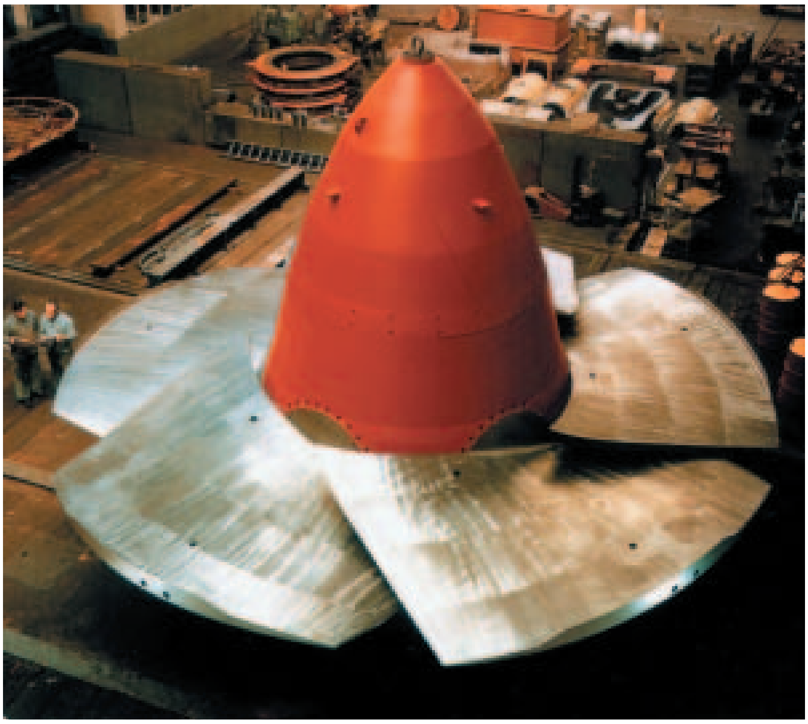
The Power Station Jupia is located at the Parana river in the state of Sao Paulo in Brazil approximately 600 km upstream of Itaipu. Jupia is operated by the Companhia Energética de Sao Paulo (CESP) just like the Ilha Solteira Power Station.

In the years 1963 to 1969 VA TECH HYDRO as a consortium partner delivered all Kaplan turbines which were equipped with 5 blade runners. In total 14 turbines are installed, each with 110.8 MW power output. At that time it was one of the largest hydropower stations ever built.

In a Kaplan runner blade the concentration of the stresses has its peak at the intersection between blade and blade disc. To reduce these stress peaks, so called undercuts are milled at these sections. The blades for Jupia were the first ones to be designed and manufactured in this way according to a global patent.

Today these undercuts are a worldwide standard. Additionally these blades were one of the first ones with anti cavitation lips. These anti cavitation lips are used to protect the base material and to reduce cavitation at the hydraulic important surfaces.

Therefore, it can be stated that the turbines were at that time not only within the largest of their type, they were also the first ones where the newest and most advanced technology of VA TECH HYDRO was employed.



Technical data:		
Output:	**110.8**	**MW**
Head:	**23**	**m**
Speed:	**78.3**	**rpm**
Runner diameter:	**8,400**	**mm**

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Wallsee Austria

Located approx. 45 km downstream of Linz, the Wallsee Power Station was built in an oxbow of the Danube, where the river crosses the border between Upper and Lower Austria, in the years 1965 to 1968.

Upstream of Wallsee the Danube bends extremely, featuring sand banks and blind corners, which used to be a serious obstacle for shipping. The power plant was constructed with the so called "dry construction"-method in the dry area and a new riverbed was dug for the Danube. This method was used for the first time in Austria. VA TECH HYDRO's scope of supply includes 6 vertical shaft Kaplan turbines and 6 generators as well as the excitation & automation system.

Technical data:		
Output:	37.9 MW / 42.5	MVA
Voltage:	8	kV
Head:	11	m
Speed:	65.2	rpm
Runner diameter:	7,800	mm
Stator diameter:	12,250	mm

Kainji Nigeria

In 1962, the Federal Government of Nigeria decided to base the main supply of electricity on hydropower technology. This led to the decision to construct Kainji, the first large hydropower station in Nigeria.

Kainji Dam and Power Station are located on the River Niger in Niger State, some 350 km west of the Nigerian capital Abuja. The reservoir has a width of up to 20 kilometers and stretches back some 180 kilometers, almost reaching the border of neighbouring country Niger. Construction work at Kainji started in 1964.

In 1972, National Electric Power Authority (NEPA) awarded a contract to VOEST-ALPINE, one of the predecessors of VA TECH HYDRO, to design, manufacture and install two vertical Kaplan turbines of 108 MW maximum output. Before these two units – number 11 and 12 - were commissioned in 1974, NEPA ordered two more turbines – units 5 and 6. These two units of 128 MW output each are designed as fixed blade propeller turbines. The design challenge on all four turbines was the limitation in size: the existing turbine blocks were designed for 90 MW units only, the new units had to fit in these narrow unit bays.

Along with the six 95 MW turbines at Jebba and the four 150 MW turbines at Shiroro, VA TECH HYDRO has supplied the turbines for more than 80% of Nigeria's hydro electric capacity.

Technical data:	11/12 Kaplan	
Output:	108.1	MW
Head:	38.1	m
Speed:	115	rpm
Runner diameter:	6,500	mm

Technical data:	5/6 Propeller	
Output:	128.7	MW
Head:	38.1	m
Speed:	107.1	rpm
Runner diameter:	6,800	mm

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Jebba Nigeria

The Jebba Power Station is located at the Niger in the center of Nigeria approximately a five hours drive west from the capital Abuja.

In 1978 VA TECH HYDRO in Ravensburg was awarded with the contract to supply the 6 turbines for the power station by the Nigeria Electric Power Authority (NEPA). Montreal Engineering from Canada was the consulting company employed by the client to supervise the works at the power station. The turbines were designed as 5 blade Propeller turbines and the speciality of these turbines is, that the blades are clamped into the hub and are not fixed with any kind of screw connection.

Due to the high manufacturing quality of the spiral case, with a diameter of more than 10 m, it was not required to press out the spiral case. The power station has no shut off device. Therefore the turbine will only be stopped by closing the wicket gates.
During commissioning in 1982 / 1983 Montreal Engineering and NEPA observed immediately that the wicket gates were very tight since no noise from the leakage water could be heard. This extreme tightness was archived with the conical machined pre-stressed wicket gates.

Technical data:		
Output:	102.7	MW
Head:	29.3	m
Speed:	93.75	rpm
Runner diameter:	7,100	mm

Kotapanjang Indonesia

Located right at the equator in the Riau province in Central Sumatra / Indonesia, the Kotapanjang Power Plant was built for the client PT. PLN (Persero). The generated power is required for the further industrial development in the Pekanbaru area. Since the crises in Southeast Asia the Kotapanjang project is one of the key projects in the grid system for the Riau and West Sumatra Areas.

VA TECH HYDRO's delivery included three vertical generators, the main transformers, generator switchgear and balance of plant equipment (station service equipment including station service transformers, emergency Diesel, batteries, chargers and inverters, uninterrupted power supply and the control system), fire fighting equipment, telecommunication and grounding system.

Also included in the scope was the design, manufacturing, transportation, erection, commissioning as well as the training of the operation staff. All three units are in successful commercial operation since November 1998.

Technical data:		
Output:	**45**	**MVA**
Voltage:	**11**	**kV**
Speed:	**200**	**rpm**
Stator diameter:	**5,900**	**mm**

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Zilina Slovakia

The power plant of Zilina is located on the river Vah approximately 200 km north/east of Bratislava nearby the city of Zilina in Slovakia. The plant will supply the local grid with 173 GWh of electricity and is regulated also for peak load production.

Two vertical Kaplan turbines have been installed utilizing 320 m^3/s of the river discharge. It was on 28th of October 1994 when the consortium of ABB-SAE-SADELMI and VA TECH HYDRO signed the contract for the design, fabrication, supply and installation of the equipment. This included the following:

- Two vertical shaft Kaplan turbines including digital type governors
- Hydromechanical steel structures including three large radial spillway gates, stoplogs, rakes and trashrach raking equipment
- Powerhouse crane
- Generators and electrical equipment (supplied by ABB).

Start of construction was in October 1994 and four years later in January and April 1998 the two Kaplan turbines were successfully commisioned and handed over to the client VODNE DIELO ZILINA (VDZ), a subsidiary company of the Slovakian Energy Supply Company VODNE ELECTRARNE TRENCIN.

Technical data:		
Output:	**38.1**	**MW**
Head:	**25.8**	**m**
Speed:	**150**	**rpm**
Runner diameter:	**4,800**	**mm**

Candonga
Brazil

The Candonga Power Station is located on the river Rio Doce in Minas Gerais near Ponte Nova / Brazil and has a total capacity of 142 MW.

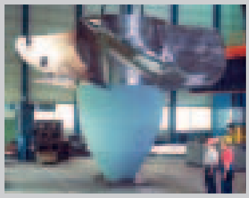
Located in the municipalities of Ponte Nove, the turnkey engineering procurement and construction (EPC) contract was won by a consortium VA TECH HYDRO BRASIL being a part of it. Work on this project is scheduled from 2001 till 2004 where the first of these three units was set into operation at the end of 2003.

For the private investors EPP and CVRD, VA TECH HYDRO supplied the complete electromechanical equipment including three vertical Kaplan units, the hydro-mechanics, the three generators, substation and transmission line, main transformers, protection, excitation and control system

as well as the auxiliaries and all the engineering, design, manufacture, transport, erection and commissioning work of the plant.

Technical data:		
Output:	47.6 MW / 53	MVA
Voltage:	13.8	kV
Head:	48.6	m
Speed:	225	rpm
Runner diameter:	2,840	mm
Stator diameter:	6,500	mm




VA TECH HYDRO worldwide

VA TECH HYDRO can point to more than 160 years of experience in hydraulic power generation and is a competent partner for sustainable solutions.

Set-ups in Austria, Brazil, Canada, China, Colombia, France, Germany, Hungary, India, Indonesia, Iran, Italy, Malaysia, Mexico, Norway, Poland, Russia, South Africa, Spain, Switzerland, Thailand, Turkey, United Kingdom, Ukraine, USA, Venezuela and Vietnam.

VA TECH HYDRO

e-mail: contact@vatech-hydro.com

Penzinger Strasse 76
A-1141 Vienna, Austria
Phone: (+43/1) 89 100 - 2963
Fax: (+43/1) 89 100 - 3821

Lunzerstrasse 78
A-4031 Linz, Austria
Phone: (+43/732) 6987 - 3451
Fax: (+43/732) 6980 - 2554

Escher-Wyss-Strasse 25
D-88212 Ravensburg, Germany
Phone: (+49/751) 83 - 2941
Fax: (+49/751) 83 - 3280

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